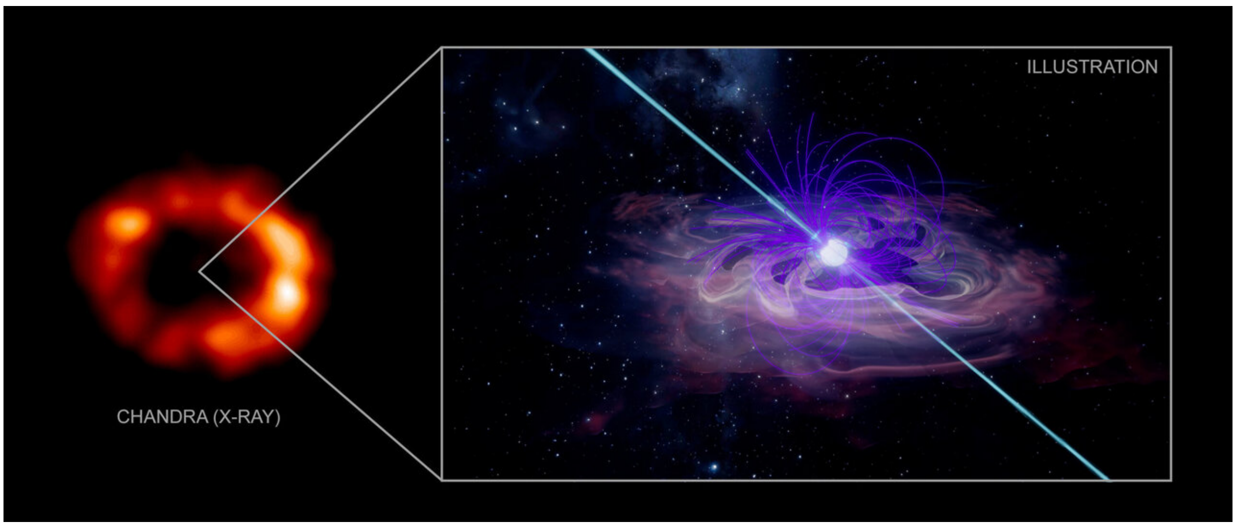
# Reclusive neutron star may have been found in famous supernova

February 23 2021, by Calla Cofield




On the left, data from NASA's Chandra X-ray Observatory shows a portion of the remains of an exploded star known as supernova 1987A. On the right, an illustration of what may lie at the center of the supernova remnant, a structure known as a "pulsar wind nebula." Credit: NASA/CXC

What remains of the star that exploded just outside our galaxy in 1987? Debris has obscured scientists' view, but two of NASA's X-ray telescopes have revealed new clues.

Since astronomers captured the bright explosion of a star on Feb. 24, 1987, researchers have been searching for the squashed stellar core that should have been left behind. A group of astronomers using data from NASA space missions and ground-based telescopes may have finally found it.

As the first supernova visible to the naked eye in about 400 years, Supernova 1987A (or SN 1987A for short) sparked great excitement among scientists and soon became one of the most studied objects in the sky. The supernova is located in the Large Magellanic Cloud, a small companion galaxy to our own Milky Way, only about 170,000 light-years from Earth.

While astronomers watched debris explode outward from the site of the detonation, they also looked for what should have remained of the star's core: a neutron star.

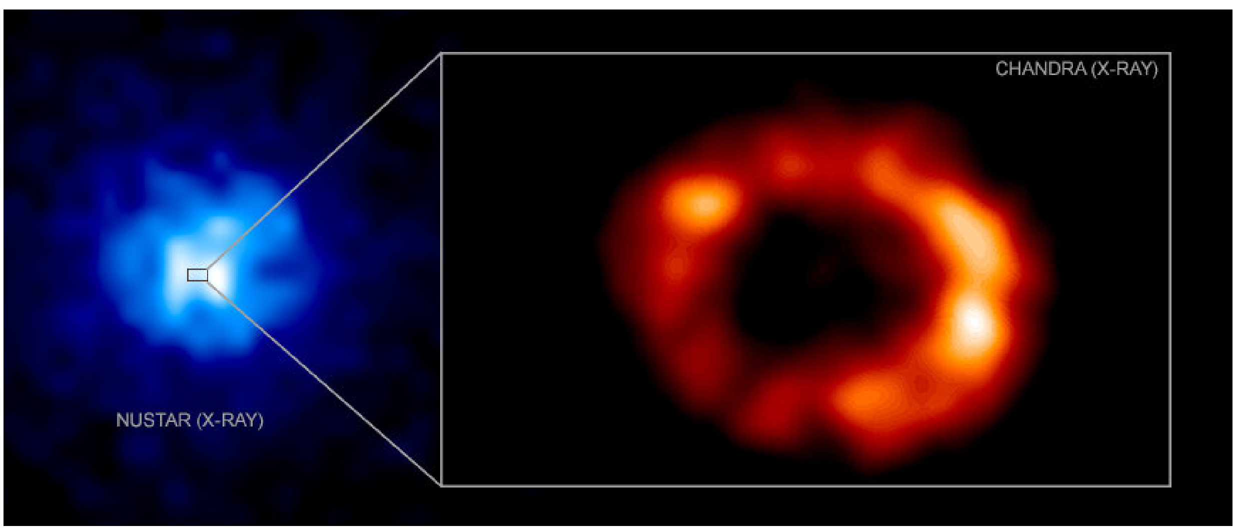
Data from NASA's Chandra X-ray Observatory and previously unpublished data from NASA's Nuclear Spectroscopic Telescope Array (NuSTAR), in combination with data from the ground-based Atacama Large Millimeter Array (ALMA) reported last year, now present an intriguing collection of evidence for the presence of the neutron star at the center of SN 1987A.

"For 34 years, astronomers have been sifting through the stellar debris of SN 1987A to find the neutron star we expect to be there," said the leader of the study, Emanuele Greco, of the University of Palermo in Italy. "There have been lots of hints that have turned out to be dead ends, but we think our latest results could be different."

When a star explodes, it collapses onto itself before the outer layers are blasted into space. The compression of the core turns it into an extraordinarily dense object, with the mass of the Sun squeezed into an object only about 10 miles across. These objects have been dubbed neutron stars, because they are made nearly exclusively of densely packed neutrons. They are laboratories of extreme physics that cannot be duplicated here on Earth.

Rapidly rotating and highly magnetized neutron stars, called pulsars, produce a lighthouse-like beam of radiation that astronomers detect as pulses when its rotation sweeps the beam across the sky. There is a subset of pulsars that produce winds from their surfaces—sometimes at nearly the speed of light—that create intricate structures of charged particles and magnetic fields known as "pulsar wind nebulae."

With Chandra and NuSTAR, the team found relatively low-energy X-rays from SN 1987A's debris crashing into surrounding material. The team also found evidence of high-energy particles using NuSTAR's ability to detect more energetic X-rays.




Supernova 1987A exploded more than 30 years ago and is still surrounded by debris. The energetic environment has been imaged by NASA's Nuclear Spectroscopic Telescope Array, or NuSTAR (shown in blue) and the Chandra X-ray Observatory (shown in red), which has finer resolution. Credit: NASA/CXC

There are two likely explanations for this energetic X-ray emission: either a pulsar wind nebula, or particles being accelerated to high energies by the blast wave of the explosion. The latter effect doesn't require the presence of a pulsar and occurs over much larger distances from the center of the explosion.

The latest X-ray study supports the case for the pulsar wind nebula—meaning the neutron star must be there—by arguing on a couple of fronts against the scenario of blast wave acceleration. First, the brightness of the higher-energy X-rays remained about the same between 2012 and 2014, while the radio emission detected with the Australia Telescope Compact Array increased. This goes against expectations for the blast wave scenario. Next, authors estimate it would take almost 400 years to accelerate the electrons up to the highest energies seen in the NuSTAR data, which is over 10 times older than the age of the remnant.

"Astronomers have wondered if not enough time has passed for a pulsar to form, or even if SN 1987A created a black hole," said co-author Marco Miceli, also from the University of Palermo. "This has been an ongoing mystery for a few decades, and we are very excited to bring new information to the table with this result."

The Chandra and NuSTAR data also support a 2020 result from ALMA that provided possible evidence for the structure of a pulsar wind nebula in the millimeter wavelength band. While this "blob" has other potential explanations, its identification as a pulsar wind nebula could be substantiated with the new X-ray data. This is more evidence supporting the idea that there is a neutron star left behind.

If this is indeed a pulsar at the center of SN 1987A, it would be the youngest one ever found.

"Being able to watch a pulsar essentially since its birth would be unprecedented," said co-author Salvatore Orlando of the Palermo Astronomical Observatory, a National Institute for Astrophysics (INAF) research facility in Italy. "It might be a once-in-a-lifetime opportunity to study the development of a baby pulsar."

The center of SN 1987A is surrounded by gas and dust. The authors used state-of-the-art simulations to understand how this material would absorb X-rays at different energies, enabling more accurate interpretation of the X-ray spectrum—that is, the amount of X-rays at different energies. This enables them to estimate what the spectrum of the central regions of SN 1987A is without the obscuring material.

As is often the case, more data are needed to strengthen the case for the pulsar wind nebula. An increase in radio waves accompanied by an increase in relatively high-energy X-rays in future observations would argue against this idea. On the other hand, if astronomers observe a decrease in the high-energy X-rays, then the presence of a pulsar wind nebula will be corroborated.

The stellar debris surrounding the pulsar plays an important role by heavily absorbing its lower-energy X-ray emission, making it undetectable at the present time. The model predicts that this material will disperse over the next few years, which will reduce its absorbing power. Thus, the pulsar emission is expected to emerge in about 10 years, revealing the existence of the neutron star.

A paper describing these results is being published this week in *The Astrophysical Journal*, and a preprint is available online.

**More information:** Indication of a Pulsar Wind Nebula in the hard X-ray emission from SN 1987A, arXiv:2101.09029 [astro-ph.HE] arxiv.org/abs/2101.09029

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